REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
07/01/2009	Final report	4/1/05 - 9/30/07

4. TITLE AND SUBTITLE

DURIP: Side Scan Sonar and Inertial Navigation System for AUV-Based Ocean Bottom/Sub-Bottom Mapping for Object Search/Identification

5a. CONTRACT NUMBER

5b. GRANT NUMBER

N00014-05-1-0353

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER

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Arlington, VA 22203-1995
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10. SPONSOR/MONITOR'S ACRONYM(S)

ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The objectives of the work supported under this DURIP were to acquire and integrate a set of acoustic imaging and navigation systems into the Bluefin 21 AUV operated by the Marine Physical Laboratory, Scripps Institution of Oceanography (MPL/SIO). The purpose was to be able to conduct autonomous repeat mapping surveys of the ocean bottom and sub-bottom to search for changes in properties with time with decimeter level repeatability.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Anne J. Footer
Unclassified	Unclassified	Unclassified	None	3	19b. TELEPHONE NUMBER *(Include area code)* 858-534-1802

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Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Final Report
DURIP: Side Scan Sonar and Inertial Navigation System for AUV-Based Ocean Bottom/Sub-Bottom Mapping for Object Search/Identification

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LONG-TERM GOALS

The long-term goals of this project were to fully equip our Bluefin 21 autonomous underwater vehicle (AUV) with acoustic and optical imaging and navigation systems to permit very wide band, high resolution, repeat mapping studies of the ocean bottom and sub-bottom.

OBJECTIVES

The objectives of the work supported under this DURIP were to acquire and integrate a set of acoustic imaging and navigation systems into the Bluefin 21 AUV operated by the Marine Physical Laboratory, Scripps Institution of Oceanography (MPL/SIO). The purpose was to be able to conduct autonomous repeat mapping surveys of the ocean bottom and sub-bottom to search for changes in properties with time with decimeter level repeatability.

APPROACH

The original approach presented in the DURIP proposal was to acquire a fiber-optic-gyro-based inertial navigation system (INS) and a payload midsection with syntactic foam, along with a combination side scan sonar and sub-bottom profiler system for our Bluefin 21 AUV. However, after the proposal was submitted, funds were obtained to purchase an INS as part of a joint program between the Scripps Institution of Oceanography and British Petroleum. In addition, a payload midsection and syntactic foam were acquired by other means. Therefore, the approach taken in this project, in consultation with the ONR program manager, was somewhat modified from that in the original proposal. The combination side-scan sonar (SSS)/sub-bottom profiler (SBP) from EdgeTech, the most expensive component in the proposal, still was acquired as originally proposed. This full spectrum chirp SSS operates at the dual frequencies of 120 kHz and 410 kHz, and the SBP operating frequency band is 2-12 kHz. The remaining funds were redirected to acquire additional imaging systems, and to pay for the full system integration and testing by Bluefin Robotics, Inc. One imaging system that

Bluefin integrated into the AUV is a new-design multibeam sonar system specifically made for AUVs by Imagenex Technology Corp. This multibeam system is a model 837 Delta T profiling sonar with an operating frequency of 260 kHz, a maximum depth rating of 6000 m, a cross-track angular resolution of 0.75 deg over a 120-deg interval, and 3-deg resolution along-track. Its weight, size, and cost are several times smaller than existing multibeam systems. Another imaging system purchased for the AUV is an optical camera and strobe system. The digital camera provides 6.1 Mpixel resolution, comes in a 2000-m depth-rated housing, and obtains illumination from the 200 Joule strobe.

A key aspect of the approach was to leverage the development of the AUV acoustic imaging and navigation systems acquired under this grant to the maximum extent possible with other ongoing programs at MPL/SIO. One such program was the Seafloor Geohazards project, a joint effort between SIO and British Petroleum. The purpose of this project was to develop technologies to measure seafloor changes and deformation down to the millimeter level over areas ranging from 0.5 to tens of kilometers and on time scales of a few weeks to several years (D'Spain *et al*, 2006a). Another project that was leveraged with this DURIP was the Persistent Littoral Undersea Surveillance Network (PLUSNet) program, part of the Office of Naval Research's (ONR) Code 32 6.2 Discovery and Invention research program. The objective of this 3-year program was to develop a semi-autonomous controlled network of fixed bottom and in-water mobile platforms (both prop-driven AUVs and underwater gliders) using environmentally and tactically adaptive processing to enhance the detectability and tracking of quiet submerged targets in shallow water environments of operational interest.

Autonomous vehicle technology is revolutionizing U.S. Navy operations (The Navy UUV Master Plan, 2004). These points are illustrated by the success of prop-driven AUVs for addressing the mine countermeasure problem and the rapidly expanding use of existing gliders for long-duration sensing of oceanographic fields. The technology also is revolutionizing other areas of oceanographic research. The funding from this DURIP grant has permitted us to take advantage of these developments. The new capabilities provided by our fully equipped and tested AUV permit numerous scientific studies in the future.

WORK COMPLETED

The combination EdgeTech SSS/SBP system and topside processing system were purchased and the system arrived in house in Spring, 2006. A specially designed payload midsection and syntactic foam for the EdgeTech system also arrived in house. Once the final mechanical design and packing of all other subsystems was completed at SIO, the AUV itself, the INS (a model U-PHINS fiber-optic-gyro-based system manufactured by iXSea Corp in France that was purchased with 2004 year-end funds in the joint Scripps/BP program), the DVL, the Imagenex multibeam sonar system, the high precision long baseline navigation system, and a sound velocimeter (acquired under another project), along with their housings were shipped to Bluefin Robotics in Spring, 2006. The integration was completed and the vehicle returned to us in Spring, 2007.

IMPACT/APPLICATIONS

The relevance of developing AUV technology for the Navy's mission is detailed in the Navy UUV Master Plan (2004). Specifically for this DURIP, a mid-size AUV equipped with acoustic imaging and navigation systems to permit very wide band, high resolution, repeat mapping studies of the ocean bottom and sub-bottom has direct application to mine countermeasures, detection of bottom scour

patterns for ASW missions, studies of the nature and evolution with time of fine-scale structures on the ocean bottom, general seafloor surveys for bottom deployments, seafloor geohazards, and vehicle precision navigation. This AUV with instrumentation acquired under this DURIP provides a very useful platform for a large number of future basic research programs in the areas of geophysics, ocean acoustics and undersea signal processing, autonomous vehicle technology, oceanography, climate change, and marine biology.

REFERENCES

D'Spain, G. L., C. D. Chadwell, R. Zimmerman, and G. Openshaw (2006a). "High resolution repeat bathymetric surveys using AUVs," invited paper, World Maritime Tech. Conf., 8 pgs.

D'Spain, G. L., E. Terrill, C. D. Chadwell, J. A. Smith, and S. D. Lynch (2006b). "Active control of passive acoustic fields: Passive synthetic aperture/Doppler beamforming with data from an autonomous vehicle," J. Acoust. Soc. Am. 120 (6), 20 pgs..

Kussat, N. H., C. D. Chadwell, and R. Zimmerman (2005). "Absolute positioning of an autonomous underwater vehicle using GPS and acoustic measurements," IEEE J. Oceanic Engin. 30 (1), 153-164.

McGillivary, P., G. L. D'Spain, T. Boyd, D. Doolittle, S. Vogel, and H-W Schenke (2005). "AUVs for ANSWRS - ANtarctic Studies of the Western Ross Sea," submitted to the Marine Technology Society magazine, 4 pgs plus 5 figs.

"The Navy Unmanned Undersea Vehicle (UUV) Master Plan," (2004). Rept. submitted to ASN/RDA UUV Master Plan Oversight Board, 9 Nov, 127 pgs.

Zimmerman, R., G. L. D'Spain, and C. D. Chadwell (2005). "Decreasing the radiated acoustic and vibration noise of a mid-size AUV," J. Oceanic Engin. 30 (1), 179-187.